WLAN/WDS Performance using Directive Antennas in Highly Mobile Scenarios: Experimental Results

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Presentation Outline

- WiFi based Vehicular Communications: Challenges and Limitations
- Proposed Solution to Increase Mobility, Range and Throughput
- Field Measurements: Results and Recommendations
- Conclusions

WiFi based Vehicular Communications: Challenges and Limitations

- WiFi is the most popular Wireless IP based technology
- Exists in millions of portable devices
- It is favourable for use in future Vehicular communications

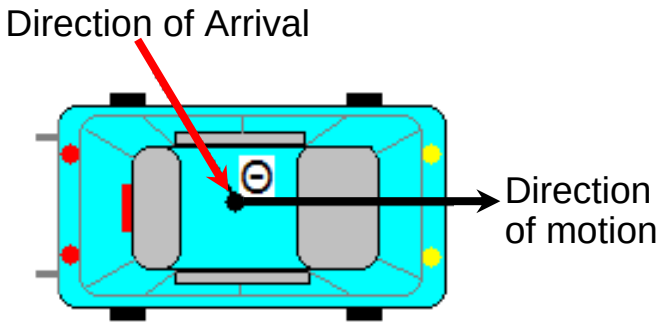
- Supports local users (i.e. with 50-100m of the AP)
- Supports limited mobility within a hotspot

- New applications, such as DVB over WiFi, require more robust communication links

Mobility Limitation

$$f_\theta = f_m * \cos(\theta)$$

$$f_m = u / \lambda$$



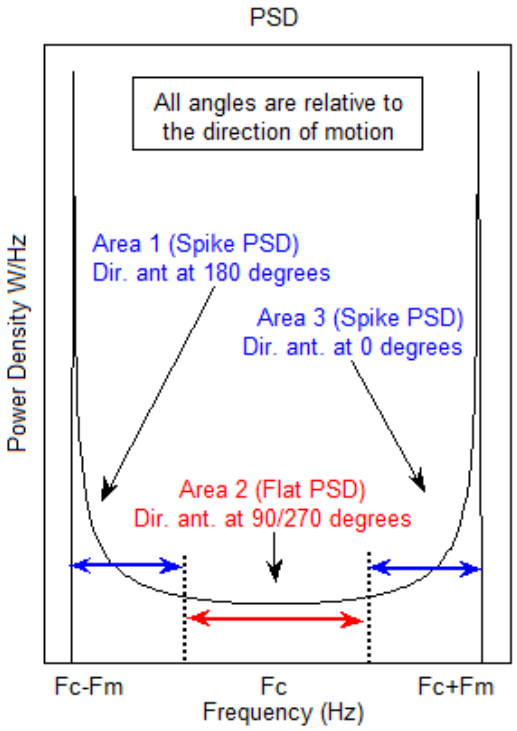
f_m : *Max. Doppler Shift*

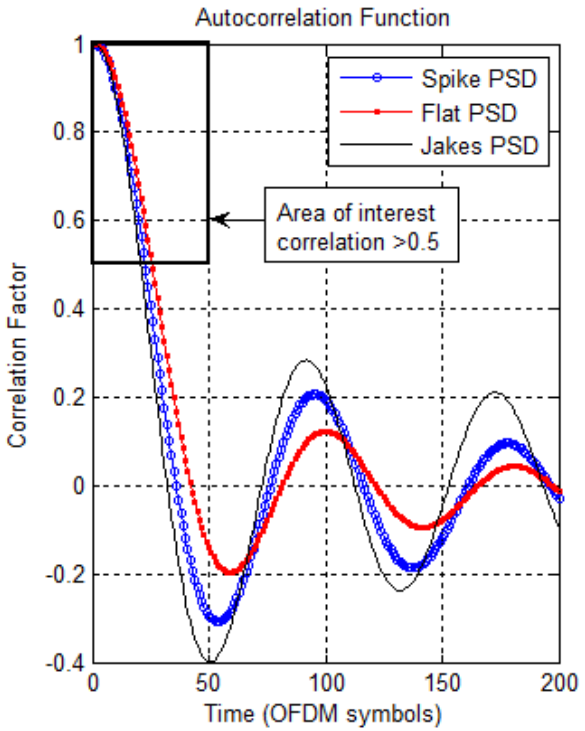
u : *Mobile speed*

λ : *Carrier Wavelength*

- High-speed motion in a multipath environment causes high Doppler spreads which in turn:
  - Increase Channel Fading Rate (LCR)
  - Reduce Coherence Time
  - Introduce an Aging Problem
- How can WiFi technology support users travelling at high speeds without increased Signal Processing?

Power Doppler Profile and Coherence Time





- Coherence Time

$$R(\tau) = FT^{-1}\{S(f)\}$$

$$T_c = \frac{\lambda/2}{u} = \frac{0.5}{f_m}$$

- Coherence time is relatively insensitive to the shape of the Power Doppler Profile, but strongly related to the rms Doppler Spread.

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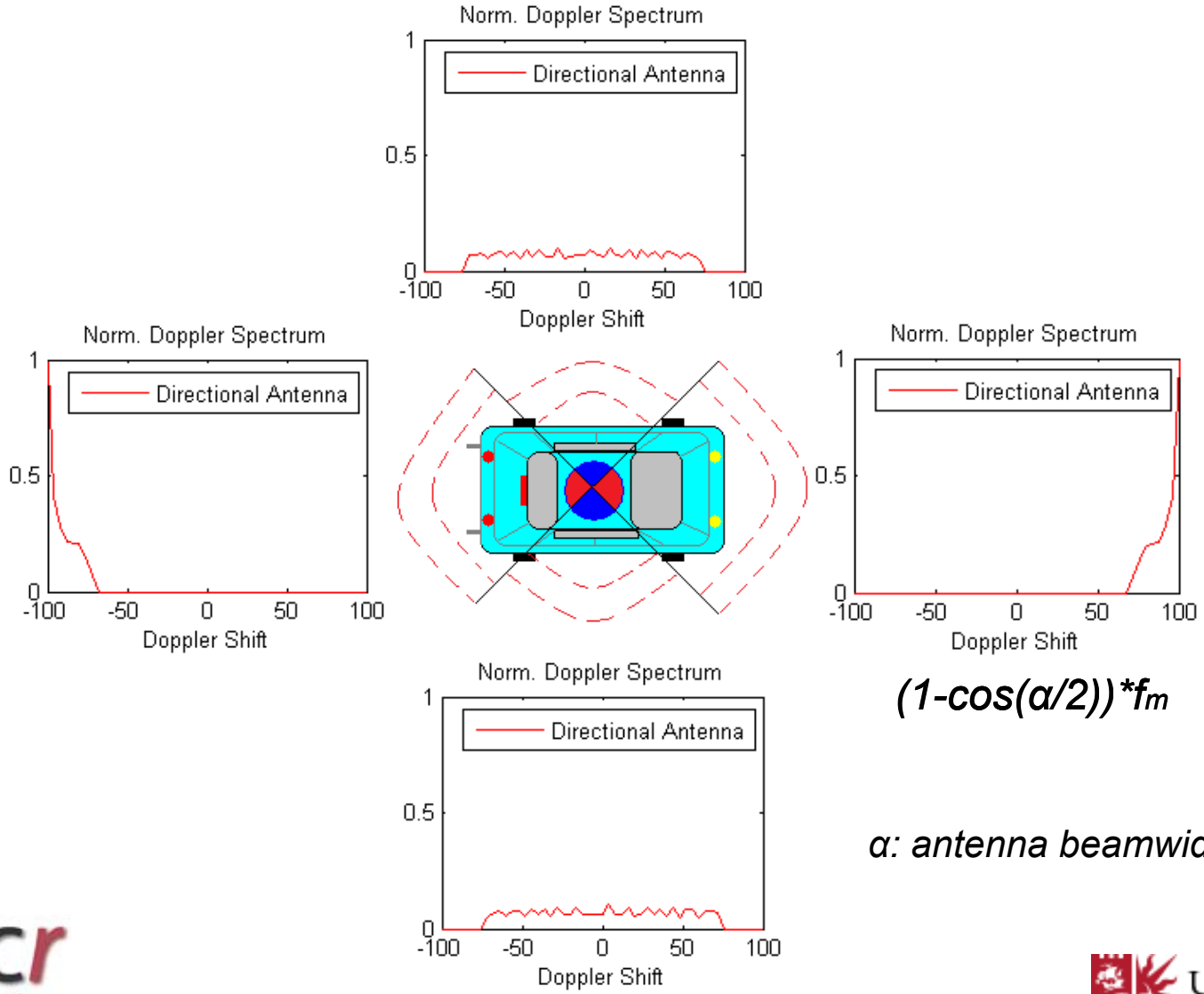
Directional Antennas can Increase Mobility, Range and Throughput

- Directional Antennas are used as Spatial Filters
- Directional Antennas offer:
  - Reduced Doppler Spread
  - Reduced Delay Spread
- When correctly aligned, they also offer:
  - Enhanced Signal Levels
  - Reduced Co and Adjacent Channel Interference

Proposed Solution



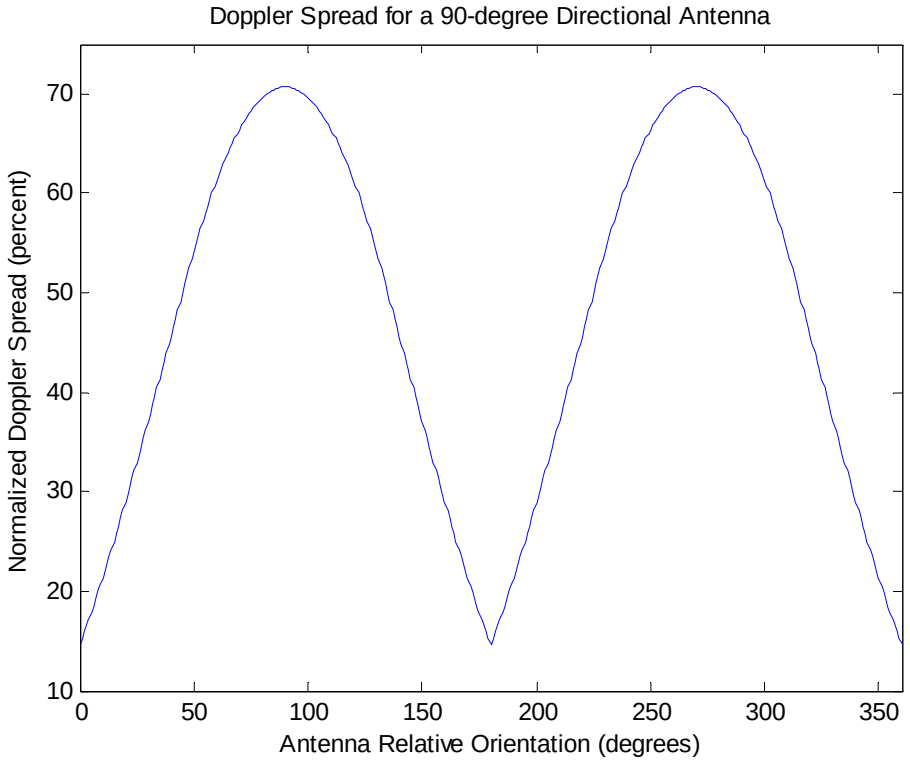
$(1-\cos(\alpha/2))*f_m$

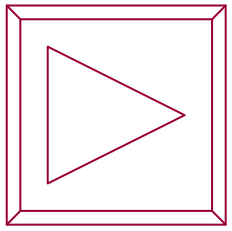
$2*f_m*\sin(\alpha/2)$

α: antenna beamwidth

Proposed Solution

Doppler reduction with a 90 degree sector

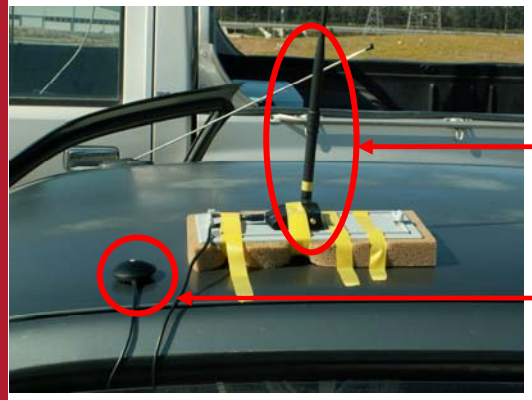




Measurements Configuration

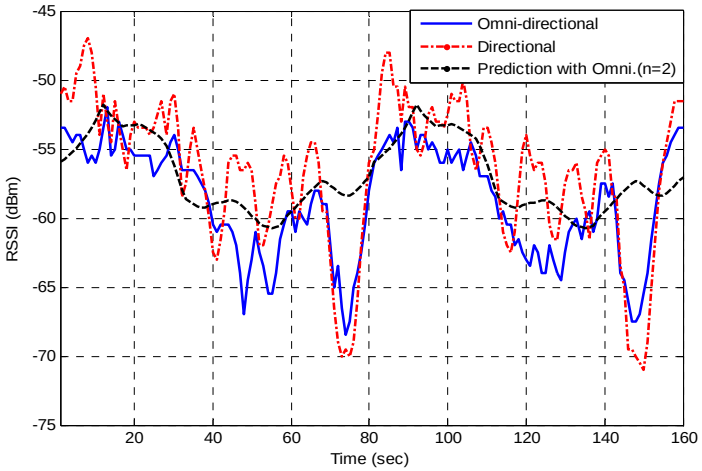
Access Point

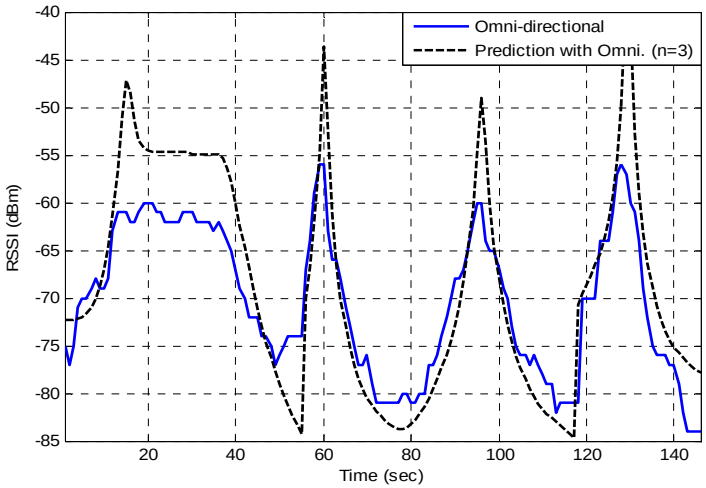
Server PC



USB WLAN card

GPS receiver





$$L_p = A + 10nLog_{10}(d/d_o) + s \qquad d \geq d_o$$

$$A = 20Log_{10}(4\pi d_o/\lambda)$$

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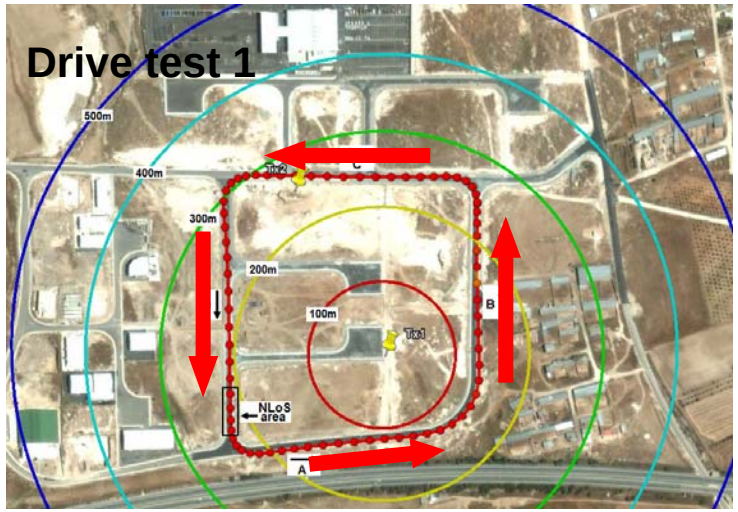
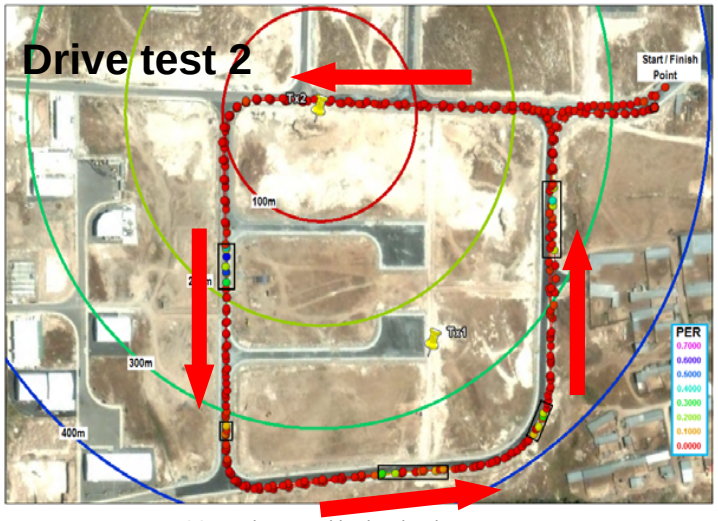
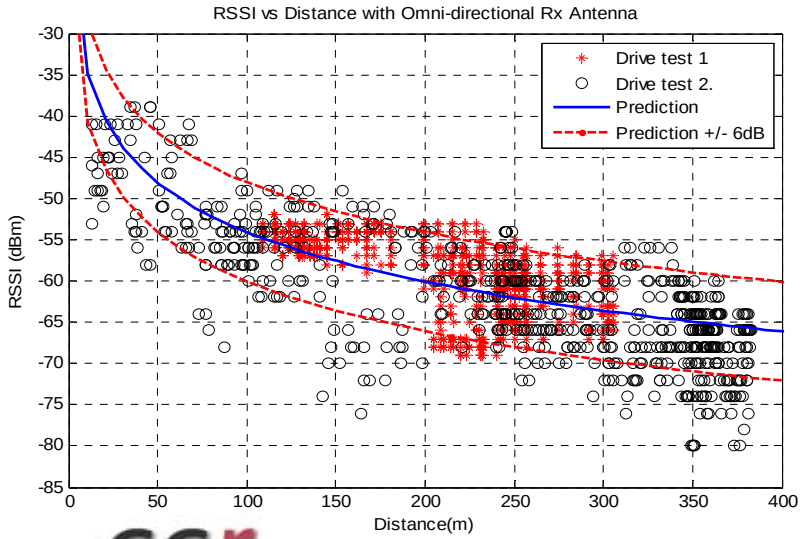
System Parameters

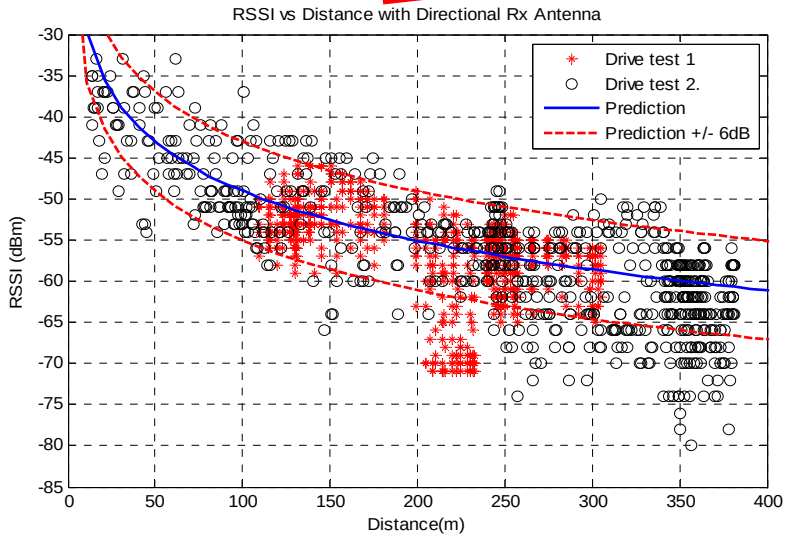
Tx Power	17 dBm
Tx Antenna Gain	6 dBi
Rx Antenna Gain (Omni.)	6 dBi
Rx Antenna Gain (Dir: 60 deg.)	10 dBi
Modes tested	QPSK 1/2, QPSK 3/4,
Packet Lengths tested	700, 900, 1100, 1300 bytes
Throughputs Tested	1, 2, 4, 8 Mbps
Protocols Used	TCP, UDP, BCT

Results from Paphos Trials









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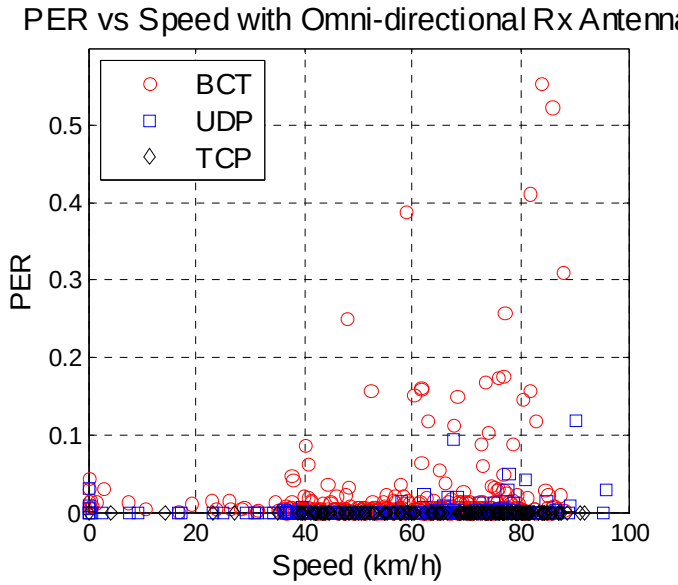
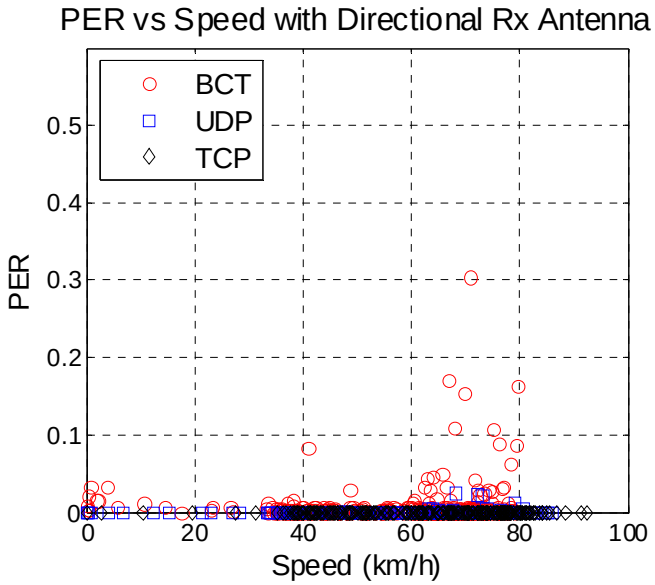
Packet Errors caused by high Doppler Spread





- The directional antenna (60 degrees) reduces the maximum Doppler Spread by at least 50%
- Assuming that 5% PER can be tolerated by the application, the directional Rx antenna offers at least 50% increase in speed for UDP and BCT

Vehicle Speed (km/h)	40	70	95
Max. Doppler Spread (Hz) Omni	178	311	422

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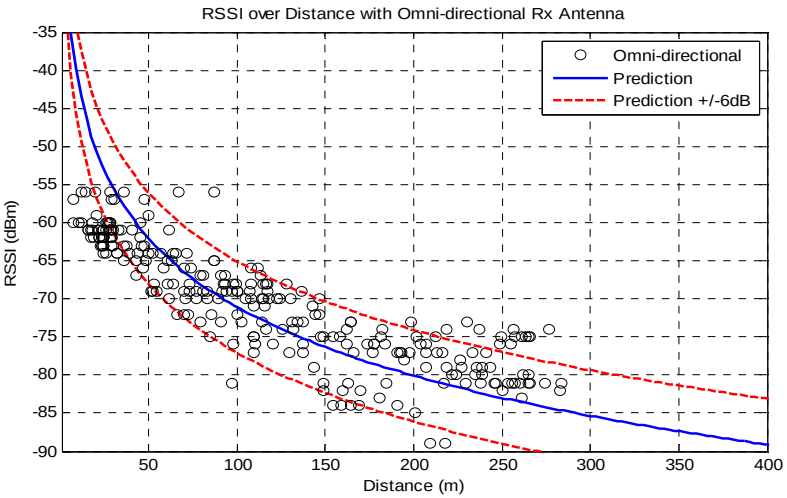
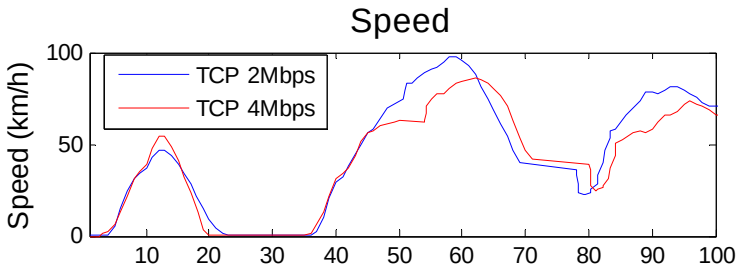
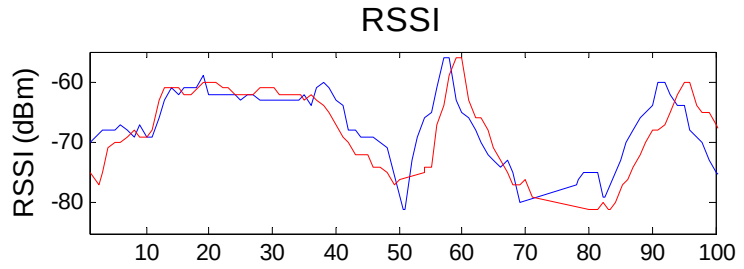
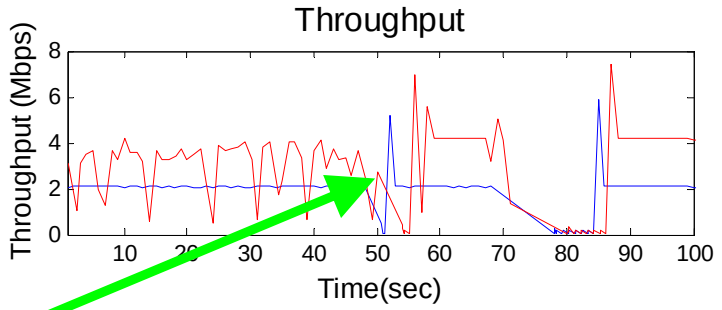
Results from Bristol Trials - WDS









- PER was always zero

Hand-over from AP2 to AP1

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Conclusions

- Directional antennas can enhance the performance of Vehicular communications not only in terms of range and throughput but also in terms of supported mobility.
- The use of sectorized or smart antennas installed on vehicles improves PER performance without the need for increased digital signal processing.
- WDS was found to operate well, extending the coverage at the expense of reduced throughput.

Questions?

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Acknowledgments: This work was partly funded by the Technology Strategy Board, UK Technology Programme: Project VISUALISE.

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